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Estimation of in situ bottom reflectance spectra

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ABSTRACT

Estimators of in situ bottom reflectivity are compared to laboratory measured spectra for several sites. Statistics are compiled on the relative fits of the estimators spectral curves to the laboratory data. A best estimator is selected based on these statistics. It is conjectured that the best in situ estimator remains the best estimate of the bottom reflectivity even in more complex ocean bottom areas where laboratory data may no longer provide accurate values for in situ sediment reflectivity.

1. INTRODUCTION

In the spring and summer of 1988, the Mapping, Charting, and Geodesy Division of the Naval Oceanographic and Atmospheric Research Laboratory (NOARL) acquired several suites of data at various eastern U.S. sites in order to support the test flights of the Airborne Bathymetric Survey (ABS) System. The sites included Duck, North Carolina; Panama City, Florida; and Key West, Florida. The data was acquired to provide environmental ground truth for the data accumulated by the ABS. For the Florida sites, a scanning spectroradiometer was used which scans both the upwelling and downwelling irradiances with a scan resolution of two nanometers over the working range of 400 nm to 700 nm. The instrument possesses a deck cell which scans on deck simultaneously with the underwater scans so that one may normalize the in-water spectra appropriately. The instrument provided ancillary information including pitch and roll, water temperature, and depth reading.

The instrument was extended approximately three meters off the sun side of the ship and lowered to a specific depth for a fixed time increment during which the instrument would initiate a scan of the spectrum. The scan requires 17 seconds to complete and, normally, both the upwelling and downwelling irradiances are collected within a two minute period.

The data collection procedure involved lowering the instrument in question to a position just above the water surface to obtain initial readings of the upwelling and downwelling irradiances. Once completed, the instrument would be placed just below the surface of the water and a second set of readings obtained. When the second set readings were completed, the instrument was lowered sequentially acquiring readings at each depth increment. The final set of readings was taken in the vicinity of the bottom at a depth to be close enough to estimate the bottom reflectance and, yet. not so close as to shadow the field of view of the cosine collector for the upwelling irradiance.

Bottom samples were collected at each station. These were shipped to the Naval Coastal Systems Center (NCSC) for laboratory measurement of their reflectance spectra. Table 1 provides a list of the station data for Key West and Panama City. The actual data sets are more extensive than what is shown in the table. However, only the ones displayed have been analyzed to date.

TABLE 1.

SITE	STA. #	LAT.	LON.	DEPTH
KW	1	$24^{o}31.17$N	$81^{o}39.25$W	10m
KW	2	$24^{o}29.59$	$81^{o}39.41$	4m
KW	3	$24^{o}29.63$	$81^{o}39.32$	6.3m
PC	1	$30^{o}05.07$	$85^{o}40.73$	3m
PC	2	$30^{o}05.56$	$85^{o}41.05$	9m
PC	3	$30^{o}05.85$	$85^{o}41.36$	5m

2. BACKGROUND

In various remote sensing equations, such as active or passive bathymetry, the value of the bottom reflectivity is an included variable indicating the influence the benthic interface has on the overall propagation of light in the upwelling irradiance stream. Moreover, in some turbid water cases light reflected from the bottom can be backscattered back into the downwelling irradiance stream and influence the spectral content of the measured signal. Hence, it is important that some method of estimating the spectral bottom reflectivity from data gathered in situ be considered. Especially, when sampling the bottom sediments for later lab analysis is not possible or sensible.

When one removes a sediment sample from a site a question arises -- does the removal of the sediment from the environment in which it was found alter the ultimate reflectivity values measured? The answer appears to depend on whether the bottom environment in question is organically rich or poor, and whether the environment is reducing or oxidizing. It may also depend on the character of the bottom sediment regardless of organic content. For example, there exists clay "fluff" layers which can form in some ocean bottom areas. If such clay sediments are taken out of the environment in which they are found and into the laboratory for spectral reflectivity analysis, the laboratory measurements are suspect because these fluff layers cannot be reconstructed in the laboratory. Similarly, sediments containing large amounts of perishable organics are difficult to keep in their original in situ condition in the laboratory.

In contradistinction, when relatively coarse sediments from well oxygenated, oligotrophic waters are taken into the laboratory for analysis, it is reasonable to expect the results to be reliable. The benthic environments in the Key West and Panama City (Gulf side) areas do meet this criteria for the reasonableness of laboratory analysis of their sediments. Hence, these spectra can be used as a reference to check the accuracy of in situ estimators which yield a spectral bottom reflectivity for these sites.

3. RESULTS AND DISCUSSION

Typical graphs composed of a laboratory spectrum and the aforementioned five estimators are shown in Figures 1 and 2. These are graphs portraying the results for station 1 in Key West and station 3 in Panama City. The five estimators used are indicated in the legend at the bottom of the graph. The first estimator, 'R(N-1)', is the recorded irradiance reflectance at the last increment station in proximity to the bottom. The second estimator, 'SSI', is the spectrum which is calculated from the in situ measurements using the Singly-Scattered Irradiance model.[1] The third estimator is a simple two-flow model that calculates the bottom reflectivity for each wavelength in question. The fourth estimator is an extrapolation of the irradiance reflectances from the surface to the bottom. The fifth estimator is the fit of a two-flow model to collected irradiance reflectance data in which the bottom reflectance is treated as a fit parameter.[2]

Generally, the lab spectra possesses a ramp appearance which differed most from the estimators in the spectral region between 600 and 700 nm. Therefore, a comparison of the estimators and the lab spectra is also made over the region 400-600 nm and these statistics compiled. Further, since there may be a DC offset between the estimators and the lab spectra, the estimators spectra were scaled to the lab data and statistics compiled for both the 400-700 nm and

400-600 nm ranges. This allowed a check on the form of each estimator spectral curve relative to the laboratory spectrum. Therefore, there are four statistical results for each estimator.

Figure 3 provides the results of the statistical calculations. The legend at the bottom of the plot indicates what the spectral range is for the estimator located on the abscissa and whether scaling has taken place. From left to right we have the 400-700 nm spectra, the 400-600 nm spectra, and the scaled 400-700 nm and 400-600 nm scaled spectra respectively. The ordinate represents the mean Chi-square statistics for all six stations. Generally, for the 400-700 nm results, the Chi-square results are large due to the large difference in the estimators and the lab results over roughly the 560 nm to the 700 nm range. Even with the scaling of the estimator spectra to the lab spectra, the relative falling off over the 400-700 nm range, although ameliorated, still produces relatively high values for the mean Chi-square. It is only when one looks over the 400-600 nm range that one sees acceptable fits of the estimators to the lab data.

4. CONCLUSIONS

The preliminary results given above indicate that one can obtain a good fit to the laboratory data over the range 400-600 nm. Considering both the scaled and unscaled results together over this range, the best estimator overall is the SSI estimator. However, in terms of simplicity, the last increment irradiance reflectance near the bottom appears to provide adequate estimation of the bottom reflectance spectra dispensing with the need for elaborate calculations.

It can be conjectured that the estimator found to give the best in situ estimation in the environments dealt with above will also be the best estimator in more complex benthic environments where laboratory spectra are no longer able to provide accurate data of the in situ reflectivity values.

5. ACKNOWLEDGEMENTS

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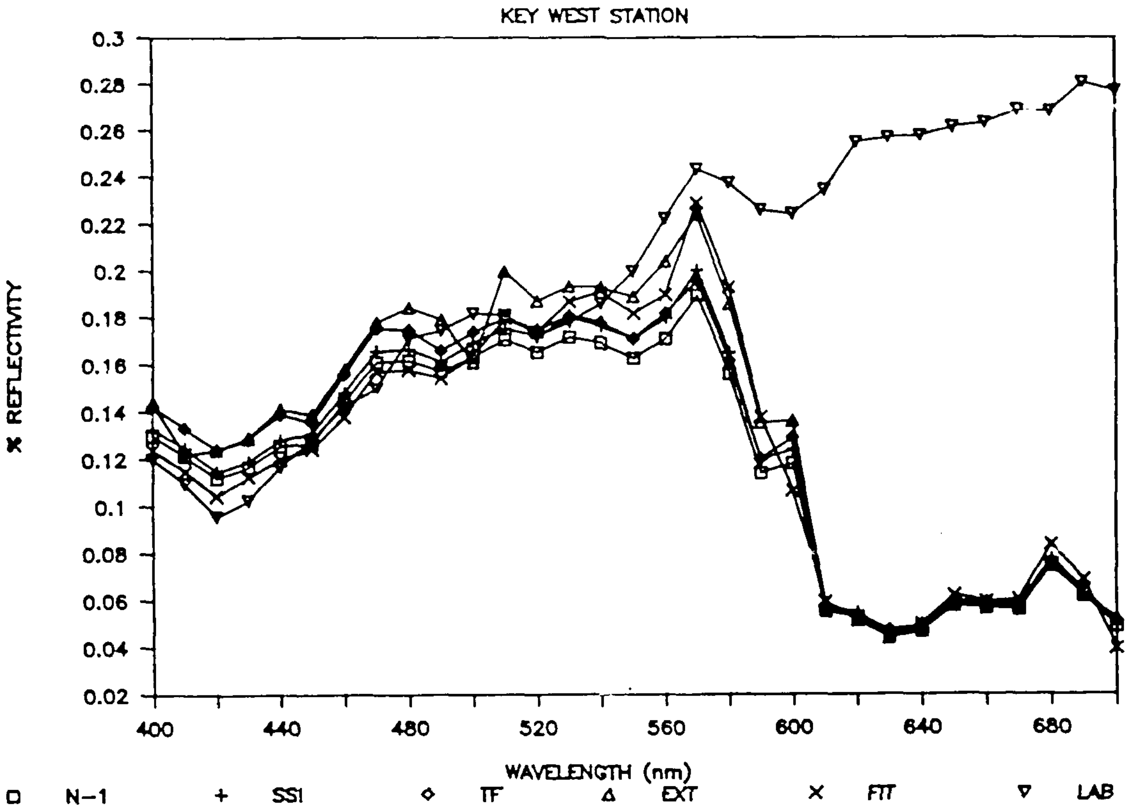
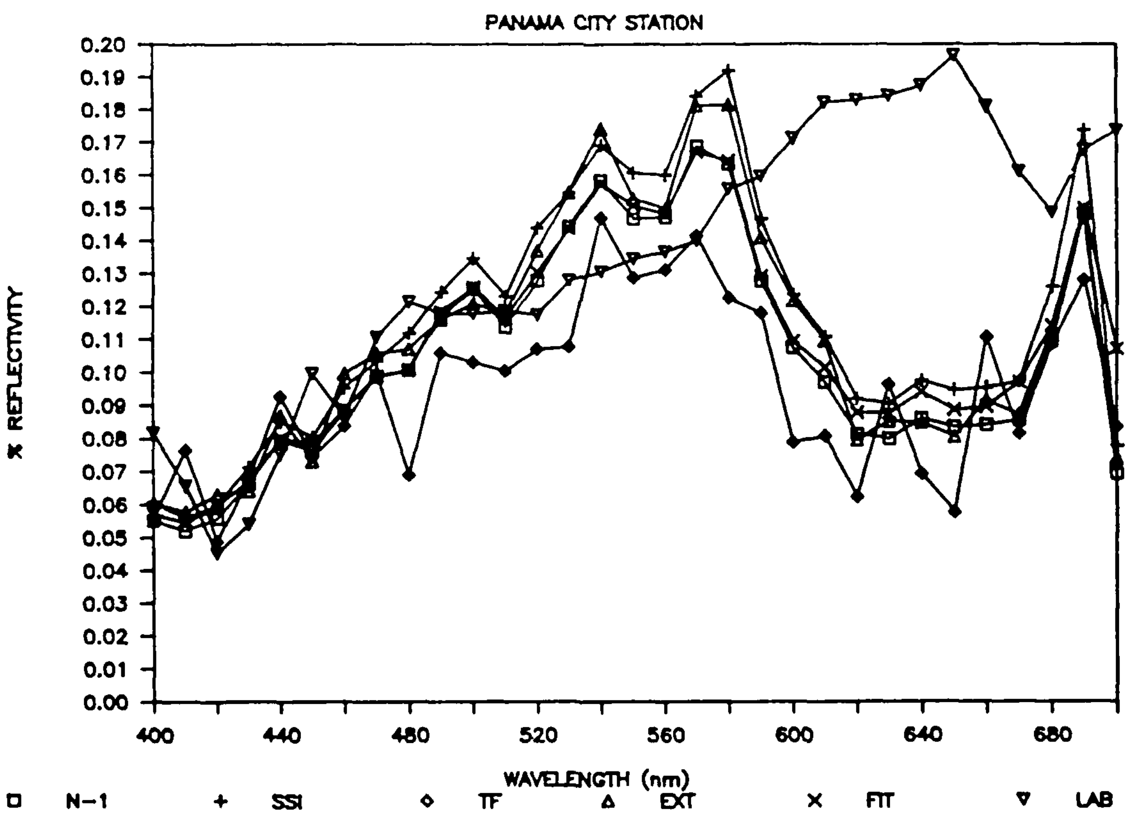
FIG.1



KEY WEST STATION
0.3
0.28
0.26
0.24
0.22
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
% REFLECTIVITY
400
440
480
520
560
600
640
680
WAVELENGTH (nm)
N-1
SSI
TF
EXT
FIT
LAB

FIG.2



PANAMA CITY STATION
0.20
0.19
0.18
0.17
0.16
0.15
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
% REFLECTIVITY
400
440
480
520
560
600
640
680
WAVELENGTH (nm)
N-1
SSI
TF
EXT
FIT
LAB

FIG.3

SUMMARY RESULTS ALL STATIONS